

The Role of Biosecurity in Preventing Foot-and-Mouth Disease (FMD) in Beef Cattle: A Review”

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Abstract

Foot-and-mouth disease (FMD) is a highly contagious viral infection that affects cloven-hoofed animals such as cattle, sheep, goats, and pigs, leading to severe productivity losses and major economic impacts. The reemergence of FMD in Indonesia in 2022, after decades of being declared disease-free, underscores the urgent need to enhance biosecurity implementation at both farm and regional levels. Biosecurity serves as the first line of defense against disease introduction and transmission through strict control of animal movement, equipment sanitation, vehicle disinfection, and human traffic management. This review comprehensively analyzes recent studies (2020–2025) from national and international scientific journals regarding the role of biosecurity in controlling FMD outbreaks in beef cattle farms. Key preventive measures include movement restriction, quarantine for newly introduced animals, regular cleaning and disinfection, proper waste management, and vaccination programs with antigenic compatibility. Integrated biosecurity systems combined with effective vaccination have been scientifically proven to reduce outbreak frequency, viral persistence, and reinfection rates within herds. Furthermore, sustainable FMD control requires enhancing farmer awareness through continuous education, providing adequate infrastructure and veterinary support, and enforcing government regulations effectively. Strengthening these strategies collectively ensures long-term disease prevention, supports livestock sector resilience, and promotes sustainable and competitive beef cattle production in Indonesia and beyond.

INTRODUCTION

Foot-and-mouth disease (FMD) is an acute, highly contagious viral infection that affects cloven-hoofed animals such as cattle, sheep, goats, and pigs. The disease, caused by Aphthovirus of the family Picornaviridae, is characterized by fever, vesicular lesions on the tongue, mouth, and feet, salivation, and lameness. Transmission occurs rapidly through direct animal contact, aerosols, contaminated fomites, vehicles, and human movement acting as mechanical vectors (Elrashedy *et al.*, 2025; Jamal *et al.*, 2025). Because of its contagious

nature and wide host range, FMD is regarded as one of the most economically devastating diseases affecting livestock globally (Wubshet *et al.*, 2024). The virus can survive for extended periods under favorable conditions, particularly in cool and moist environments, facilitating its persistence in endemic areas. FMD outbreaks cause severe trade restrictions and economic damage due to production losses, including reduced milk yield, slower growth rates, infertility, and calf mortality (Banda *et al.*, 2023; Paton *et al.*, 2019). Control strategies typically combine vaccination, surveillance, and animal movement restrictions; however, vaccination alone is insufficient, especially in cases of antigenic mismatch between vaccine strains and field isolates (Paton *et al.*, 2025; Gubbins *et al.*, 2022). In Indonesia, FMD was officially declared eradicated in 1986, a significant milestone for the livestock industry. However, in May 2022, the disease reemerged and spread rapidly across major cattle-producing provinces, exposing weaknesses in biosecurity enforcement and preparedness (Djati *et al.*, 2023; Repository Pertanian RI, 2023). The resurgence highlighted poor implementation of farm-level hygiene, inadequate quarantine systems, and uncontrolled movement of livestock (OneHealth.or.id, 2024; Syarif, 2024). Biosecurity has therefore become a cornerstone in modern beef cattle management. It refers to a structured set of preventive measures aimed at minimizing the introduction and transmission of infectious agents through traffic control, sanitation, isolation, and vaccination (Kementerian Pertanian RI, 2023; Cegah PMK, 2024). In the context of FMD, biosecurity seeks to disrupt the epidemiological chain by integrating proper farm management, facility design, and policy compliance. Several studies confirm that farms implementing strict biosecurity measures, alongside routine vaccination and active surveillance, experience substantially fewer outbreaks (Eltahir *et al.*, 2024; Willems *et al.*, 2020). This review synthesizes current scientific findings from 2020–2025 on the effectiveness of biosecurity measures in preventing FMD transmission among beef cattle. It integrates technical, behavioral, and policy-based perspectives to generate practical recommendations for strengthening FMD prevention and improving the resilience of Indonesia's beef cattle industry within the framework of global livestock health security.

RESEARCH METHODOLOGY

This article was prepared using the literature review method, focusing on scientific publications related to the role of biosecurity in preventing and controlling foot-and-mouth disease (FMD) in beef cattle. Data and materials were collected from both national and international sources published within the last five years (2020–2025). The databases searched included ScienceDirect, Scopus, PubMed, Frontiers, and Google Scholar, as well as institutional and governmental repositories such as the Ministry of Agriculture of Indonesia, OneHealth Indonesia, and the Agricultural Repository of the Republic of Indonesia (Repository Pertanian RI, 2023; OneHealth.or.id, 2024). The search used combinations of relevant keywords such as “biosecurity,” “foot-and-mouth disease,” “FMD control,” “beef cattle,” and “vaccination strategy.” The inclusion criteria required that each article contained information on FMD prevention, biosecurity application, or integrated control systems in ruminant livestock. In contrast, articles focusing solely on virology or molecular vaccine design without connection to farm-level biosecurity were excluded from this review (Wubshet *et al.*, 2024; Paton *et al.*, 2025). The literature was analyzed qualitatively through thematic synthesis. The selected studies were grouped into three major themes: 1. Implementation of biosecurity measures in beef cattle farms, 2. Integration of vaccination and surveillance

systems for FMD prevention, and 3. Socio-economic and policy factors influencing biosecurity adoption at the farm and national levels (Djati *et al.*, 2023; Syarif, 2024). Each theme was discussed by comparing key findings, identifying gaps, and highlighting recommendations relevant to Indonesia's context and global livestock biosecurity standards (Banda *et al.*, 2023; Cárdenas *et al.*, 2025).

RESULTS AND DISCUSSION

Biosecurity is a preventive strategy designed to limit the introduction and spread of infectious diseases within livestock populations. In the context of beef cattle farming, it includes a set of management practices such as controlled animal movement, strict sanitation, disinfection procedures, and proper waste management (Djati *et al.*, 2023; Kementerian Pertanian RI, 2023). Studies in several regions demonstrate that farms applying consistent biosecurity standards experience lower rates of infection and faster recovery after outbreaks (Banda *et al.*, 2023; Eltahir *et al.*, 2024). According to Elrashedy *et al.* (2025), FMD transmission occurs primarily through direct animal contact and contaminated fomites, but indirect pathways, such as vehicles, feed, and human movement, can significantly contribute to viral spread. The enforcement of access control and sanitation zones within farms substantially reduces the risk of virus entry. Furthermore, disinfecting livestock transport vehicles and ensuring farm personnel follow hygiene protocols before entering animal areas have been shown to reduce environmental contamination and lower outbreak probability (Cegah PMK, 2024; Willems *et al.*, 2020).

Quarantine and Movement Control

Quarantine plays a central role in preventing the introduction of FMD. Newly purchased or transferred cattle should undergo quarantine for 14–21 days, allowing sufficient time for health observation and diagnostic testing (Paton *et al.*, 2025; Gubbins *et al.*, 2022). Failure to implement this measure has been a recurring weakness in Indonesia's livestock sector, especially during the 2022 outbreak when uncontrolled interprovincial cattle movement accelerated virus spread (OneHealth.or.id, 2024). In developed FMD-endemic regions, strict movement control measures have been proven effective in minimizing transmission. For instance, Abu Dhabi successfully reduced FMD incidence through a combination of vaccination, active surveillance, and regulated animal transportation supported by digital traceability systems (Eltahir *et al.*, 2024). Similar approaches could be adapted for Indonesian conditions to improve regional biosecurity infrastructure.

Integration of Vaccination and Biosecurity While vaccination remains one of the most effective tools in FMD prevention, it cannot work optimally without complementary biosecurity practices. Antigenic mismatch between vaccine strains and field isolates often leads to incomplete protection, making hygiene management and movement control equally essential (Paton *et al.*, 2019; Elrashedy *et al.*, 2025). The study by Peta *et al.* (2021) confirmed that consistent vaccination combined with proper disinfection and isolation protocols significantly increases antibody response and herd immunity in cattle populations. Moreover, Cárdenas *et al.* (2025) demonstrated through simulation models that FMD control programs incorporating both vaccination and strict biosecurity yield higher long-term effectiveness and lower reintroduction rates than vaccination-only approaches. Thus, government programs should promote integrated policies that balance immunization with infrastructure-based prevention systems (Repository Pertanian RI, 2023; Syarif, 2024).

Farmer Awareness and Behavioral Aspects

Human behavior and knowledge play crucial roles in determining the success of biosecurity implementation. Research in East Java and Bali reported that low awareness among farmers regarding the importance of quarantine, sanitation, and personal hygiene contributes to weak biosecurity enforcement at the field level (Djati *et al.*, 2023). Education and training programs are therefore essential to transform farmer behavior toward proactive disease prevention. Additionally, social and economic factors influence the adoption of biosecurity measures. High operational costs, limited access to disinfectants, and a lack of incentives reduce compliance among smallholders (Rusman *et al.*, 2024; Potensi Pengembangan Peternakan, 2025). Public-private partnerships could help bridge these gaps by providing subsidized inputs, training modules, and technical supervision.

Policy and Institutional Support

The sustainability of FMD prevention efforts relies heavily on government policy and institutional support. In Indonesia, the Ministry of Agriculture has issued several regulations and standard operating procedures (SOPs) emphasizing biosecurity enforcement, vaccination coordination, and disease reporting systems (Kementarian Pertanian RI, 2023). However, challenges remain in field implementation due to resource limitations and the absence of consistent monitoring systems (Syarif, 2024).

International collaboration, particularly through organizations such as FAO and WOA, provides an opportunity to strengthen national FMD control frameworks by integrating Indonesia's surveillance data into global monitoring networks (Wubshet *et al.*, 2024). The development of national digital livestock databases and early warning systems could further enhance outbreak response efficiency.

Overall, the reviewed literature consistently highlights that biosecurity and vaccination must operate synergistically. The absence of one reduces the effectiveness of the other, and long-term success depends on integrating technical, behavioral, and institutional dimensions into a unified disease prevention framework (Paton *et al.*, 2025; Eltahir *et al.*, 2024).

CONCLUSIONS AND SUGGESTION

Biosecurity serves as a cornerstone in the prevention and control of foot-and-mouth disease (FMD) in beef cattle production. The reviewed studies consistently demonstrate that effective implementation of biosecurity, through controlled animal movement, quarantine, disinfection, and waste management, can significantly reduce the likelihood of FMD outbreaks (Djati *et al.*, 2023; Kementarian Pertanian RI, 2023). When integrated with targeted vaccination and surveillance systems, biosecurity practices not only interrupt disease transmission but also contribute to long-term herd immunity and national livestock security (Paton *et al.*, 2025; Cárdenas *et al.*, 2025). The success of biosecurity implementation, however, depends greatly on farmer awareness, adequate infrastructure, and consistent policy enforcement. Socioeconomic constraints such as limited access to sanitation facilities, insufficient government funding, and lack of technical knowledge continue to hinder optimal adoption (Rusman *et al.*, 2024; Potensi Pengembangan Peternakan, 2025). Therefore, coordinated government policies, farmer education programs, and integrated surveillance are essential for sustainable FMD control in Indonesia and globally.

In conclusion, FMD prevention requires an interdisciplinary approach combining biosecurity, vaccination, and behavior change. Strengthening institutional collaboration between government agencies, veterinary services, and local farming communities will ensure the resilience of Indonesia's beef cattle industry against future outbreaks.

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